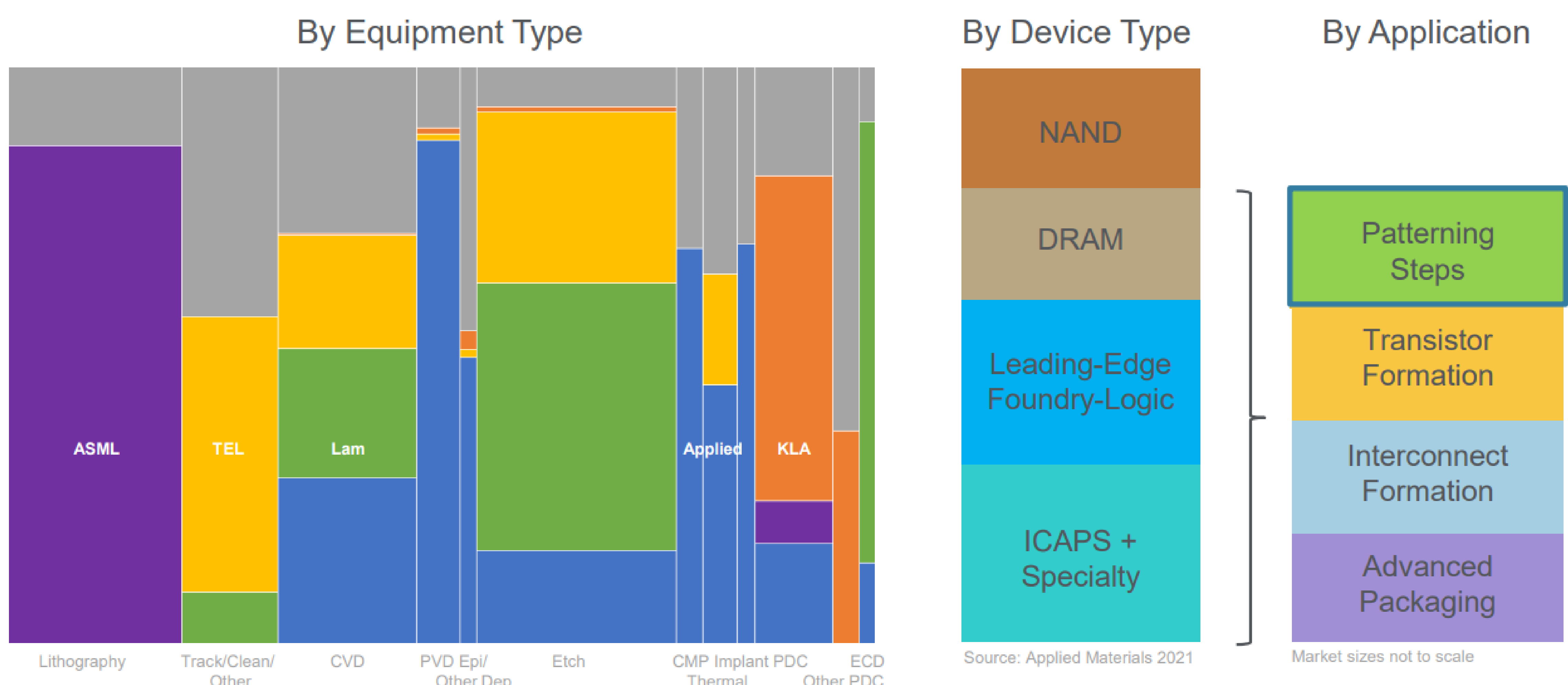
PATTERNING IN THE ANGSTROM ERA

Applied Materials News at the SPIE Advanced Lithography + Patterning Conference

February 26, 2024

Semiconductor Wafer Fab Equipment Market Segmentation



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Applied Materials Patterning Served Markets and Share

■ SAM
■ Share

Year	SAM	Share
2013	~$1.5B	~10%
2023	~$8B	~30%

* Patterning SAM and share includes Foundry/Logic and DRAM, excludes NAND

Industry's Broadest Portfolio
ALD
CMP
CVD
Etch
Metrology
Pattern Shaping
Selective Materials Removal
Thermal

Applied's patterning revenue has grown at ~2.5X the rate of WFE

Takeaway Messages

Gaining strong customer momentum with Sculpta™

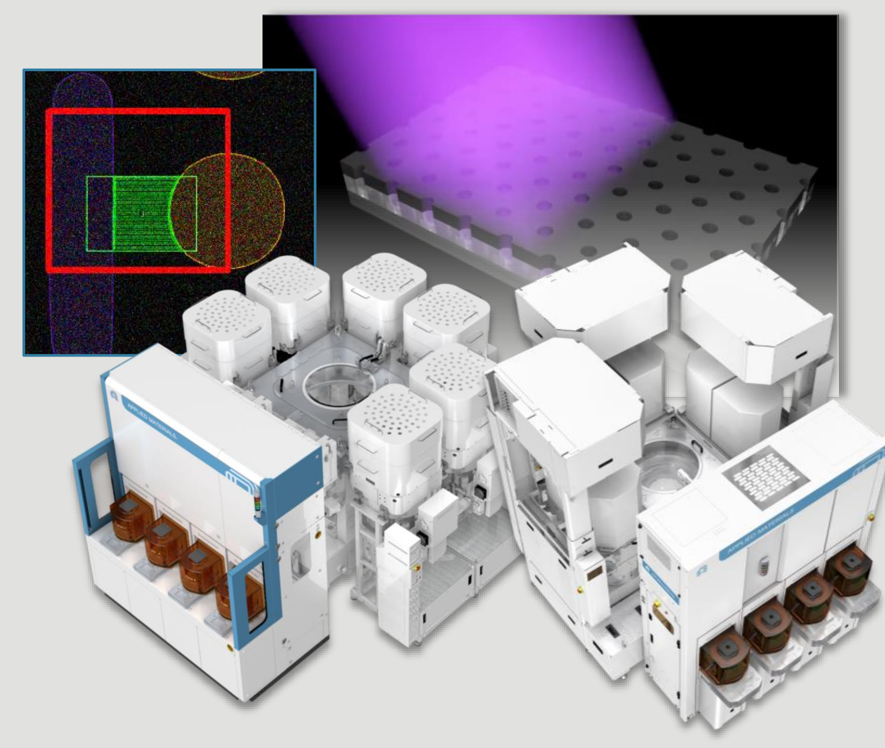
- Applied is working with all leading-edge logic chipmakers on a growing number of applications

Introducing new technologies for “angstrom era” patterning

- **Sym3™ Y Magnum™** etch heals EUV line edge roughness
- **Pioneer™ CVD patterning film** for superior sidewall uniformity
- Avoiding placement errors with **Aselta contour technology**

Growing our patterning business

- Significantly increased patterning SAM and market share with new solutions for emerging patterning challenges



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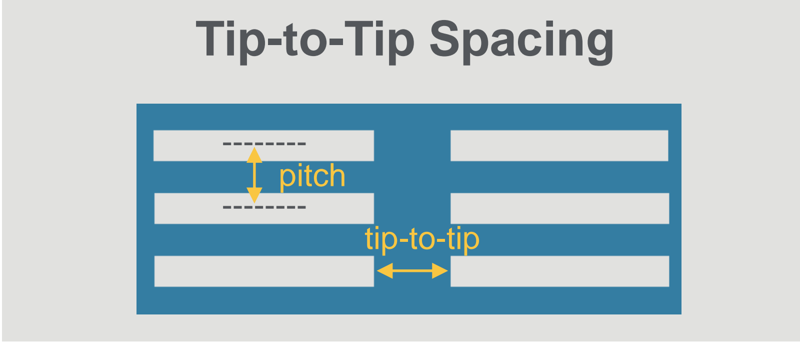
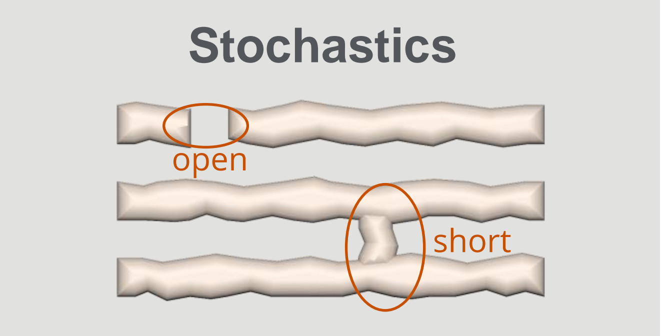
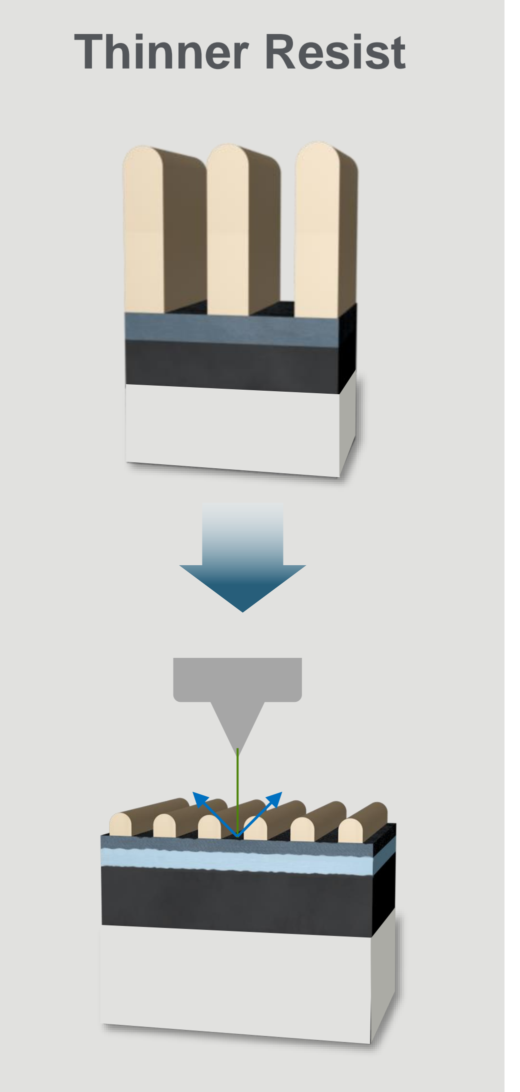
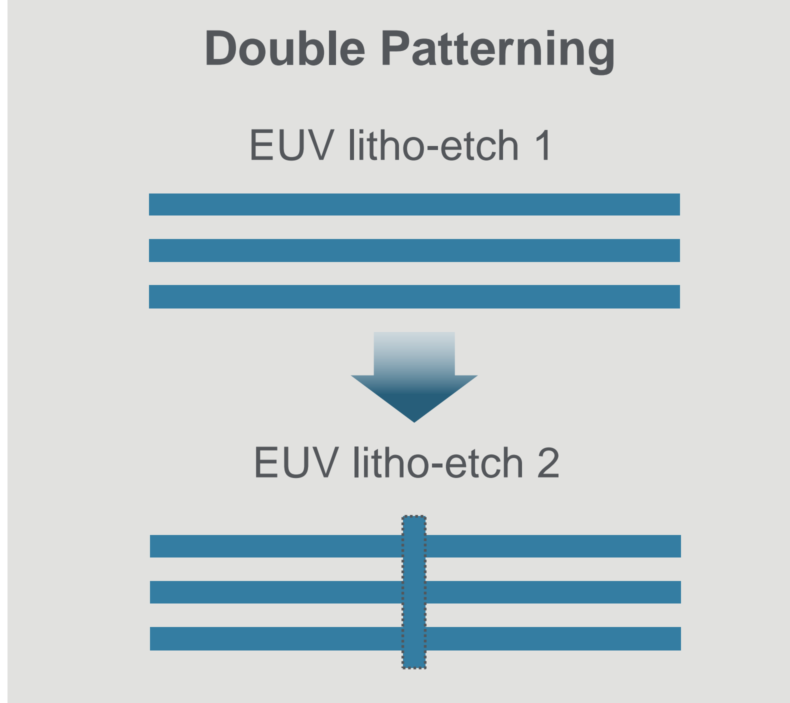
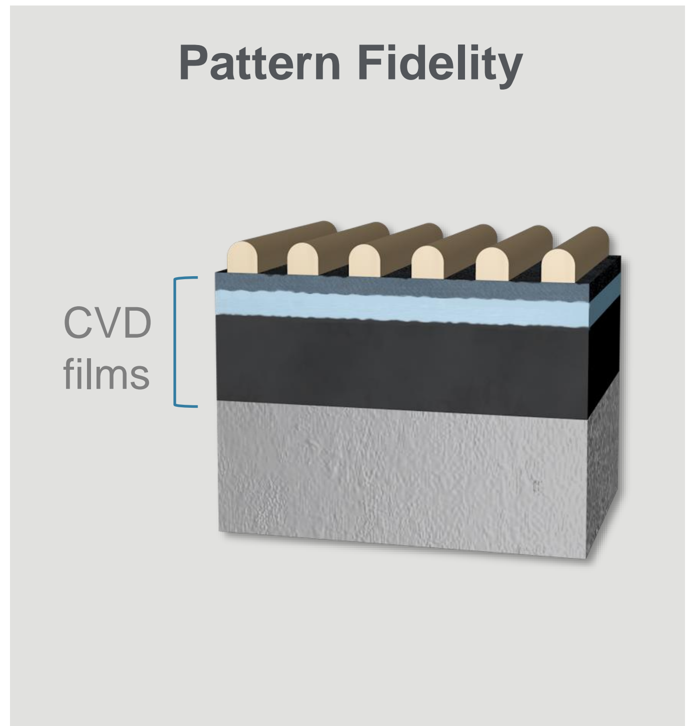
Angstrom Era Patterning Challenges











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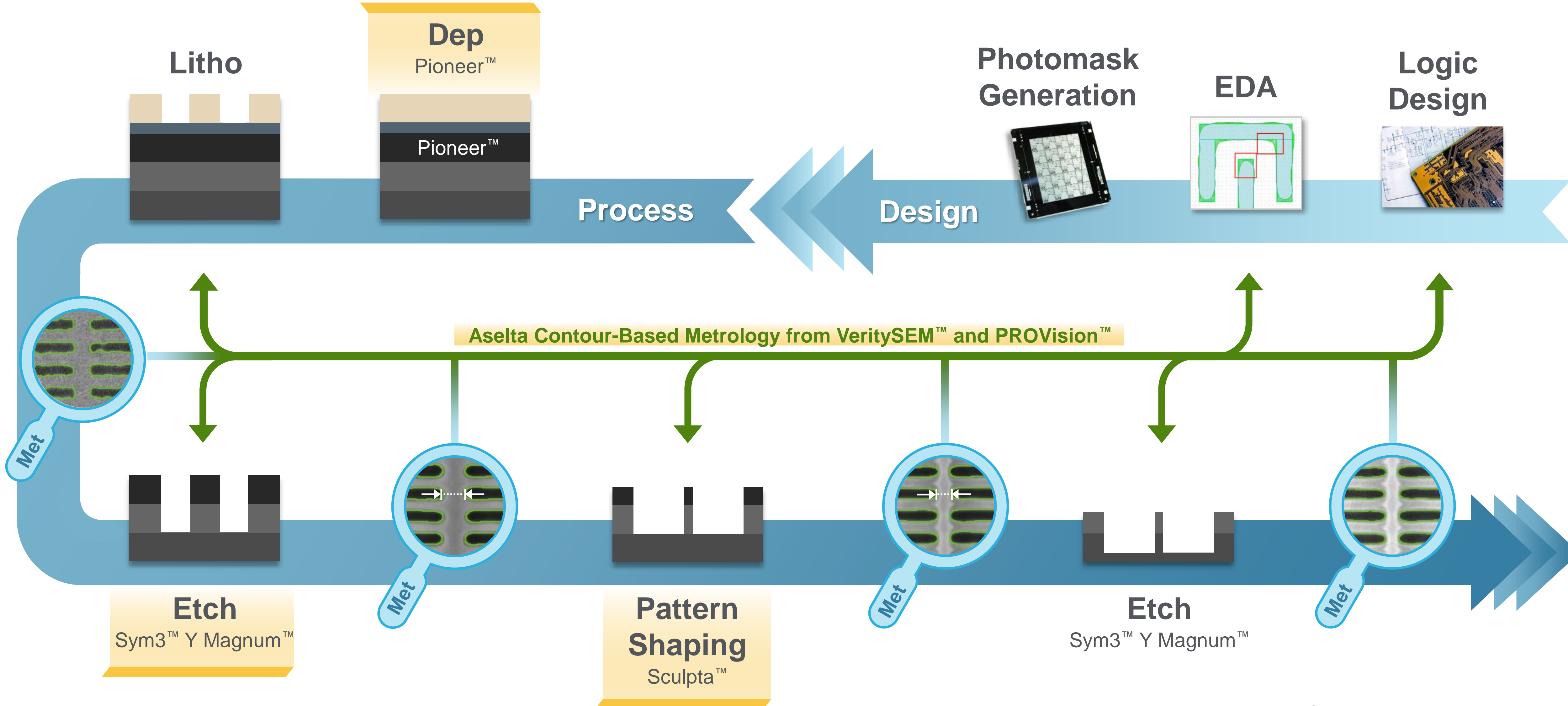
Process Innovations for the Patterning Engineer's Toolkit

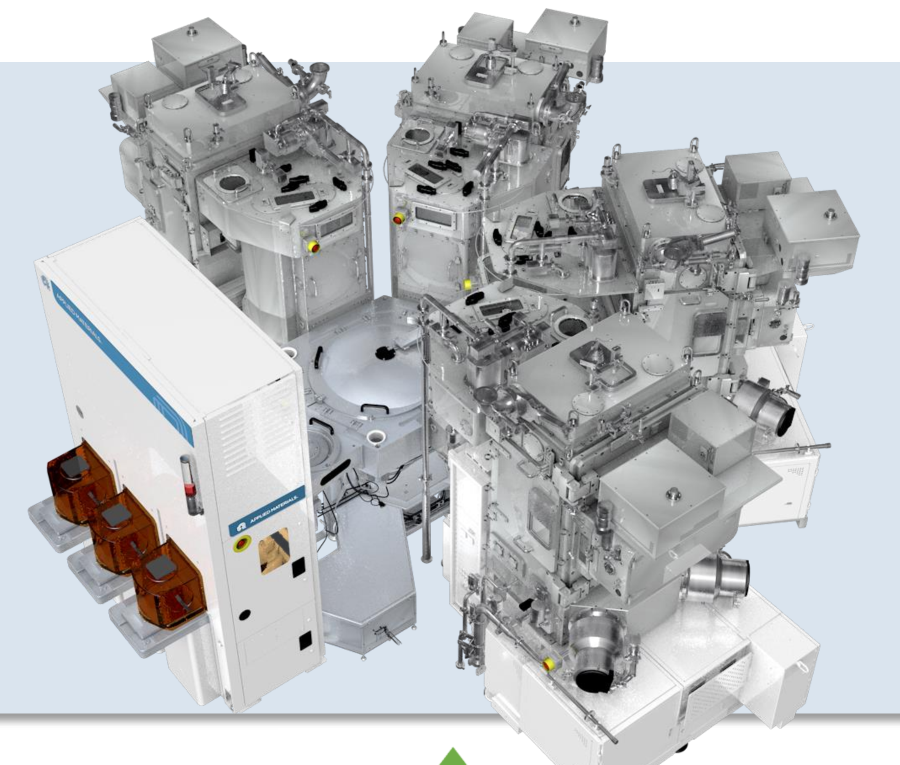


Source: Applied Materials

APPLIED MATERIALS

Centura™ Sculpta™ Pattern-Shaping System

A breakthrough innovation for the patterning engineer's toolkit



- ✓ Enhances EUV patterns to optimize chip area, reduce cost and increase yield
- ✓ Reduces patterning complexity and defects
- ✓ Reduces the environmental impact of advanced chipmaking by saving energy, materials and water
- ✓ Reduces capital and operating costs
- ✓ Helps enable high-NA EUV patterning

ecoUP

Working with all leading-edge logic chipmakers

Production tool of record for multiple layers at a leading-edge logic customer

On track for ~$200M revenue in 2024, ~$500M annually in coming years

Breakthrough Innovation for the Patterning Engineer's Toolkit

Press Release

Applied Materials Expands Patterning Solutions Portfolio for Angstrom Era Chipmaking

- *Applied is working with all leading-edge logic chipmakers on a growing number of applications for its Sculpta® pattern-shaping technology*
- *Introducing innovative new etch systems, CVD patterning films and metrology solutions to complement and improve chips made using EUV and High-NA EUV lithography*

SAN JOSE, Calif., February 26, 2024 – Today at the SPIE Advanced Lithography + Patterning conference, Applied Materials, Inc. introduced a portfolio of products and solutions designed to address the patterning requirements of chips in the "angstrom era." As chipmakers transition to process nodes at 2nm and below, they increasingly benefit

"*Pattern shaping is **an innovative solution that is helping Intel accelerate its process technology roadmap.** We are deploying Sculpta systems for our **angstrom process nodes**, with initial results showing improved throughput, enhanced wafer yield, and reduced process complexity and cost. Pattern-shaping **facilitates new strategies for advanced patterning and paves the way for pushing lithographic print boundaries.***"

- Ryan Russell, Corporate Vice President for Logic Technology Development, Intel

Breakthrough Innovation for the Patterning Engineer's Toolkit

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"*Pattern shaping is **a breakthrough technology that addresses key challenges in the EUV era**. Samsung is an early development partner and is evaluating the Sculpta systems for our 4nm process. We are looking forward to **positive results, including reduced cost and complexity and increased yield**.*"

- Jong-Chul Park, Master of Foundry Etch Technology Team, Samsung Electronics

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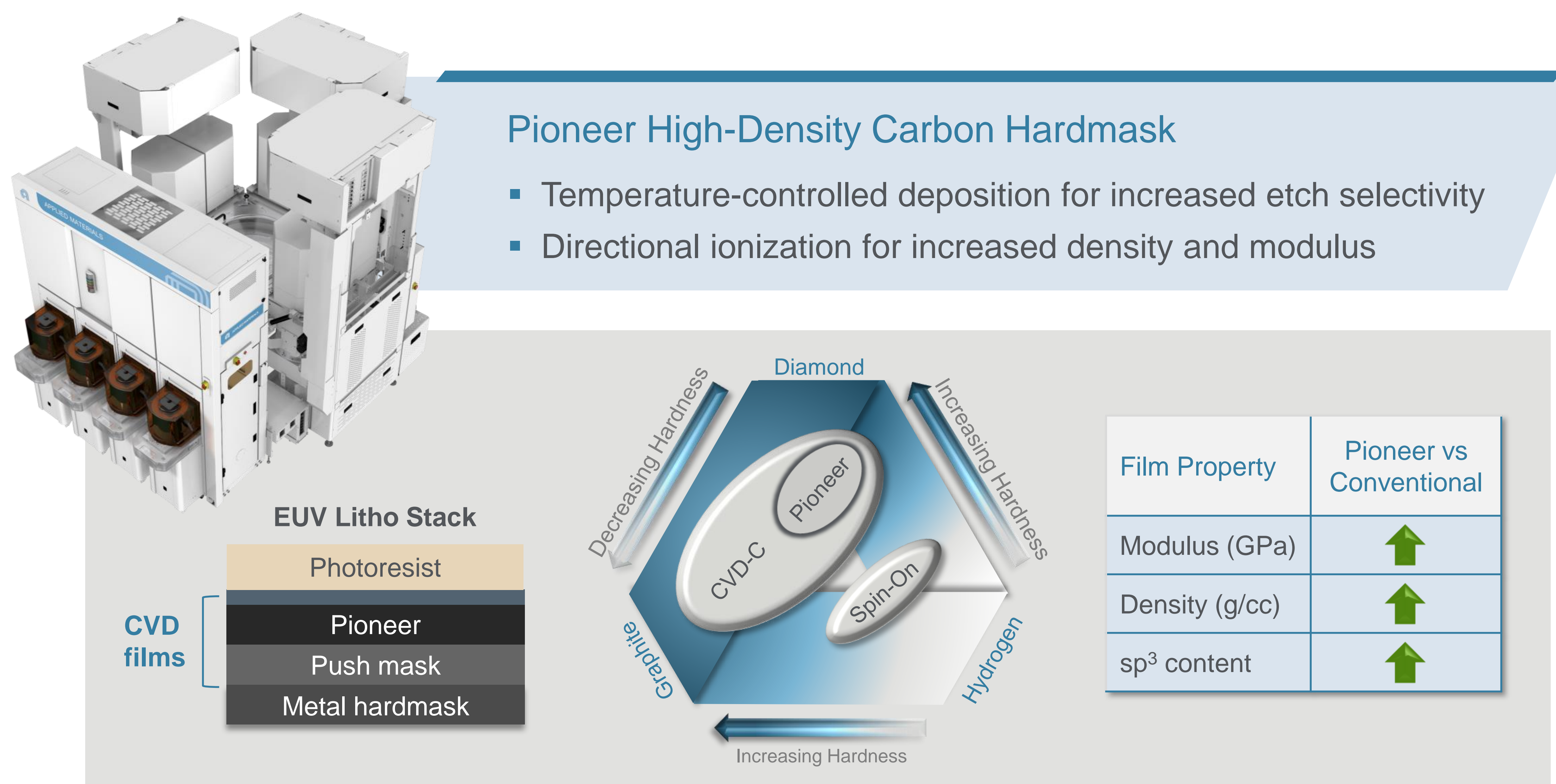
Sculpta™ Pattern-Shaping Applications

Application Type			Customer Nodes/Layers	Customer Engagements	Benefits
Tip-to-Tip Reduction	EUV double patterning step reduction		2nm and below: contact, M1, M0	lead application at multiple customers	↓Cost ↓Complexity ↓Environmental Impact
	Si area utilization improvement	Via2 35nm M3 M2 Via2 20nm	2nm: V0 1.4nm: M3/4	follow-up application	↑Density ↑Performance
NEW Bridge Defect Removal	Defect reduction		2nm: M2/3	follow-up application	↑Throughput ↑Yield

Additional applications in early development at all customers

M0-4 = metal layer
Source: Applied Materials

Producer™ XP Pioneer™ Advanced Patterning CVD Film



Film Property	Pioneer vs Conventional
Modulus (GPa)	↑
Density (g/cc)	↑
sp^3 content	↑

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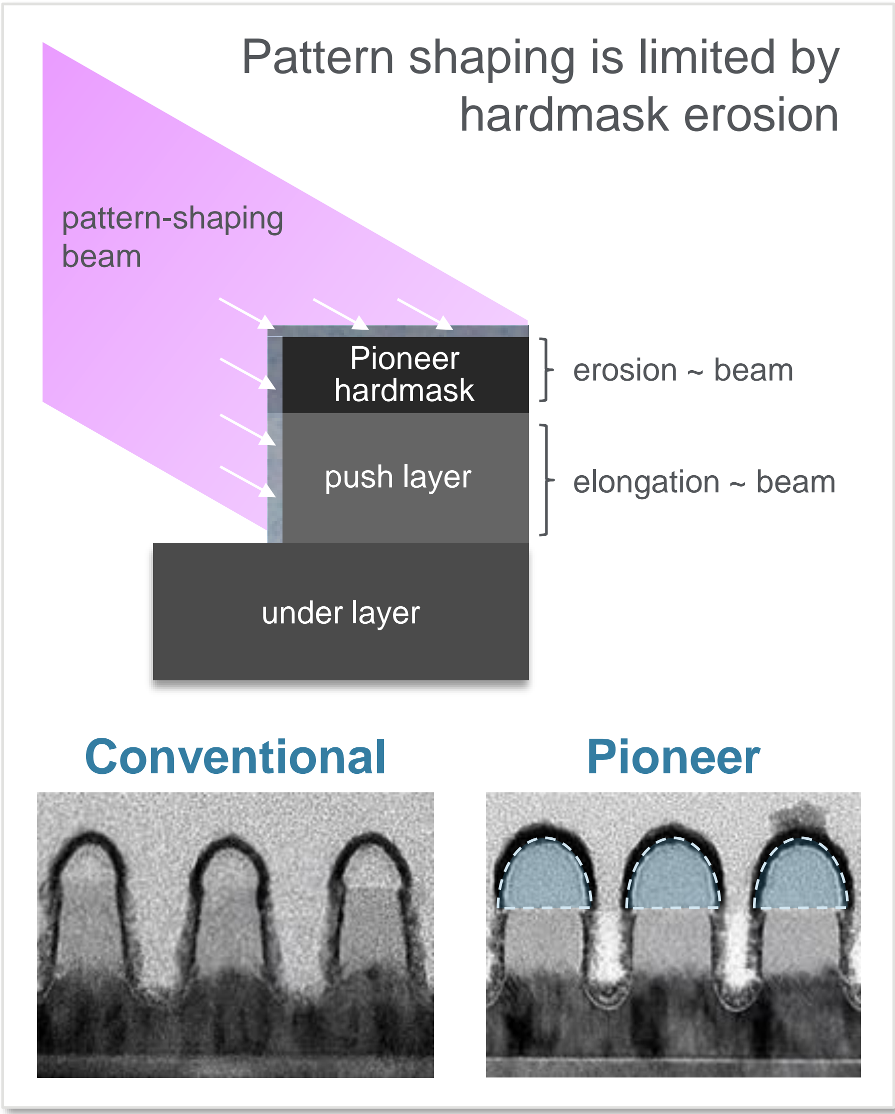
Co-optimizing Sculpta™ and Pioneer™ for EUV Patterns



Source: Applied Materials

Pattern-Shaping Performance	1.4nm Node Target	Conventional Carbon	Pioneer
tip-to-tip shrink (nm)	>10	13.0	13.1
space CD expansion (nm)	<0.5	**3**	**0**
line width roughness (nm)	<1.7	1.85	1.6

Data from Applied Materials internal test structures.

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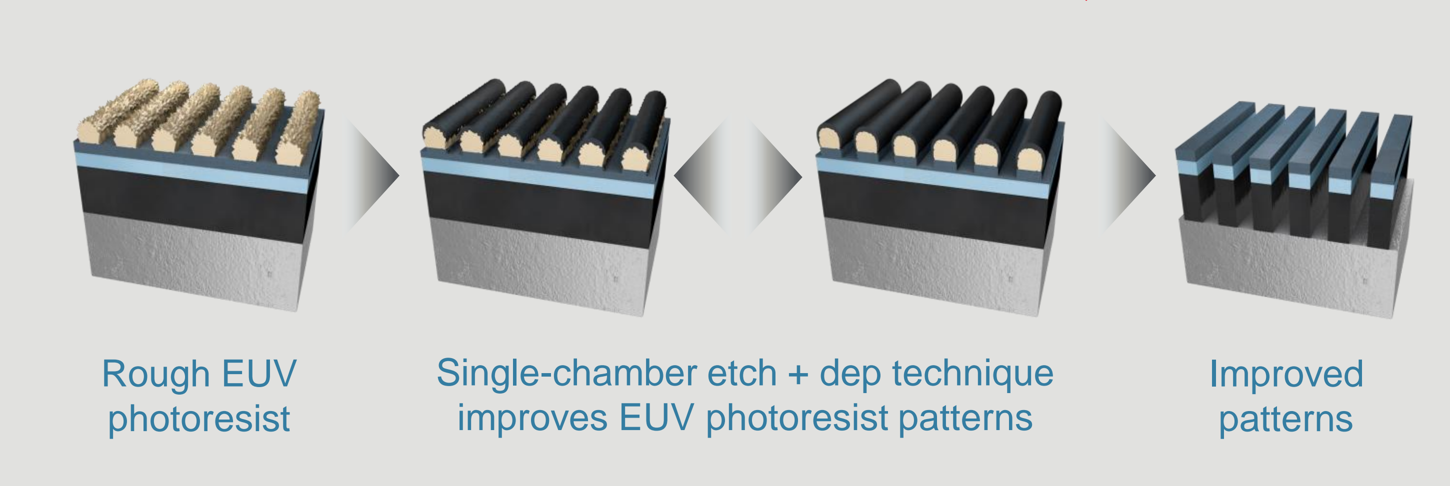
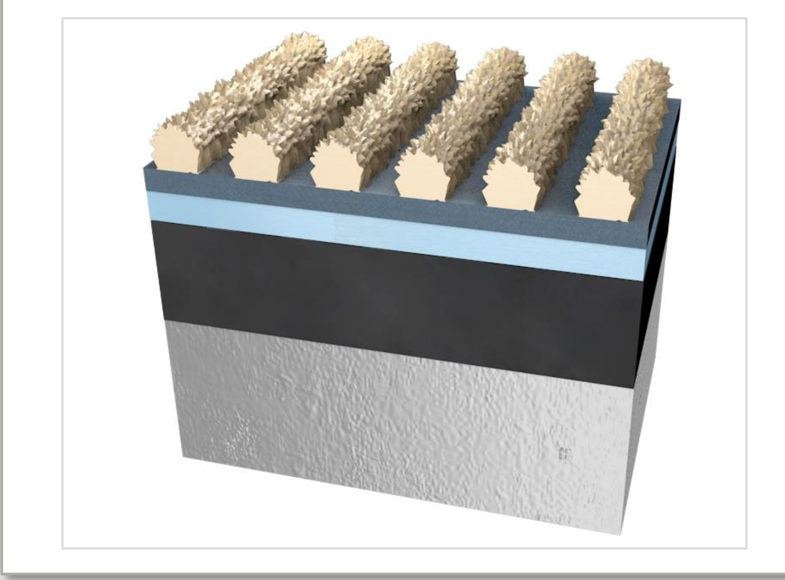
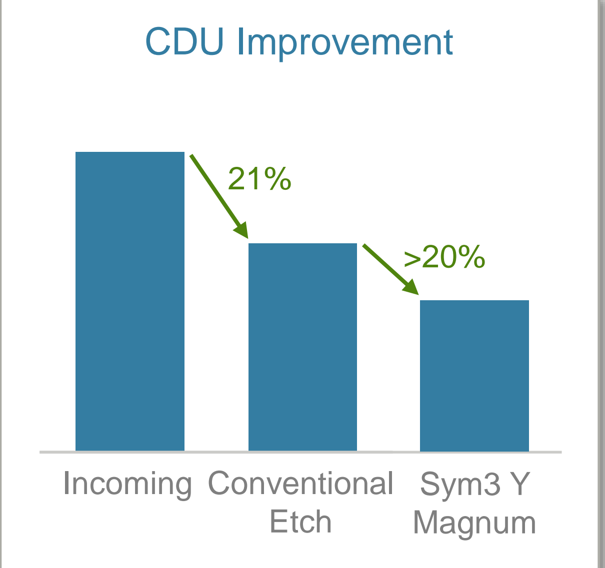
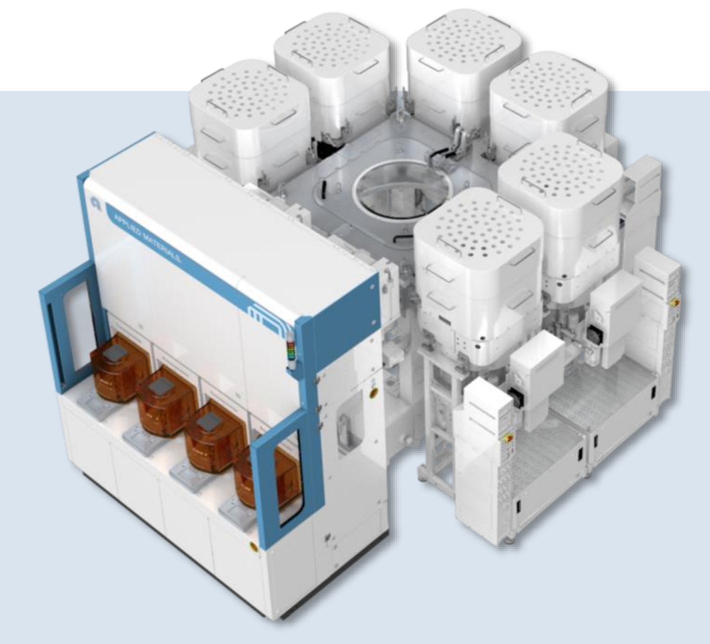
Centris™ Sym3™ Y Magnum™ Etch









- Alternate between deposition and etch in the same chamber
- **New** multi-state pulsing improves control of photoresist profile
- Symmetry of gas flow, plasma and wafer temperature produces uniform results across the wafer
- High conductance quickly removes by-products

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Sym3™ Y Magnum™ Heals Stochastic Errors

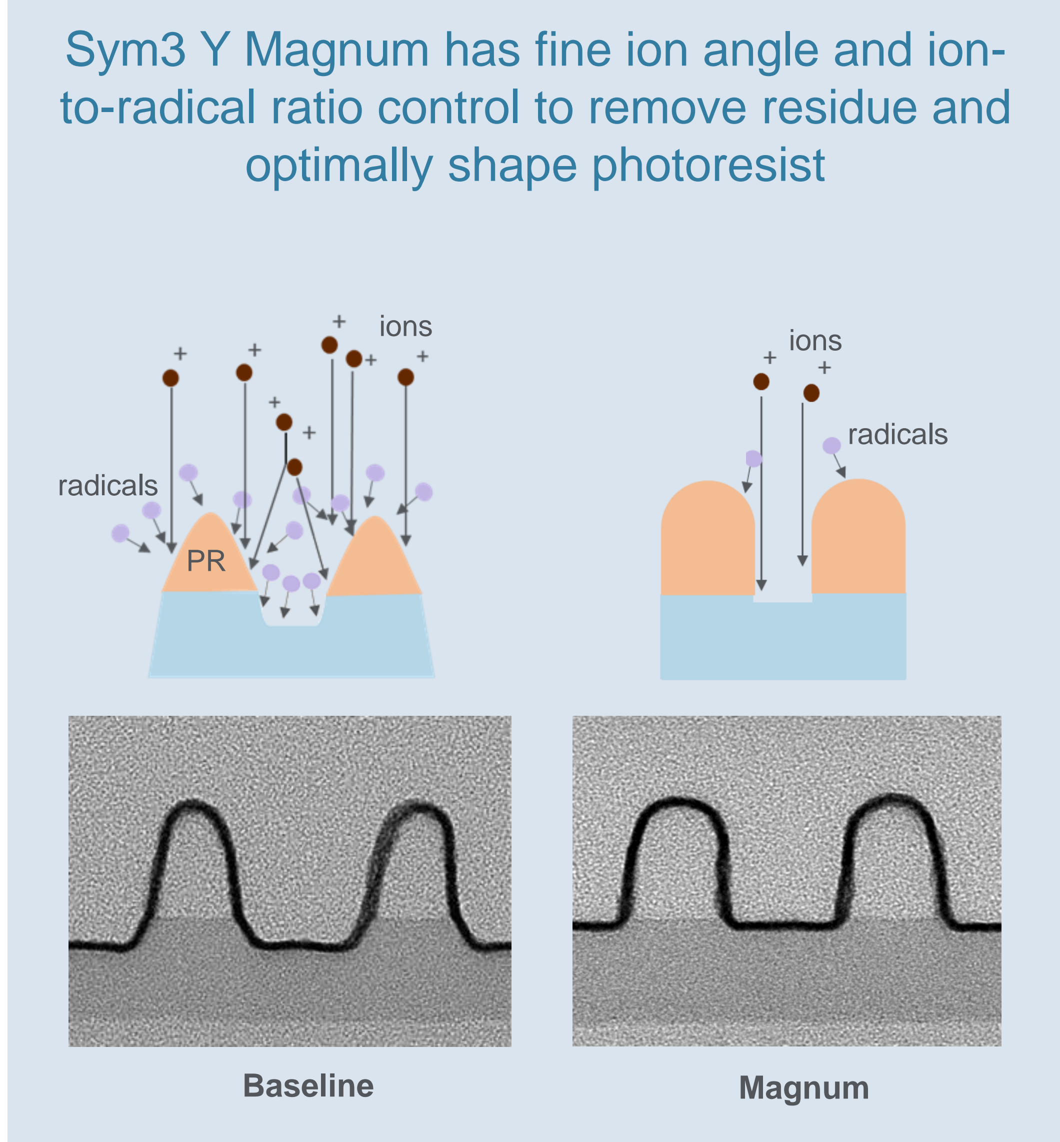
EUV creates stochastics …

Incoming photoresist

Residue
causes "bridges" that become open circuits

Notches
indentations between lines (due to damaged photoresist) lead to shorts

Source: Applied Materials



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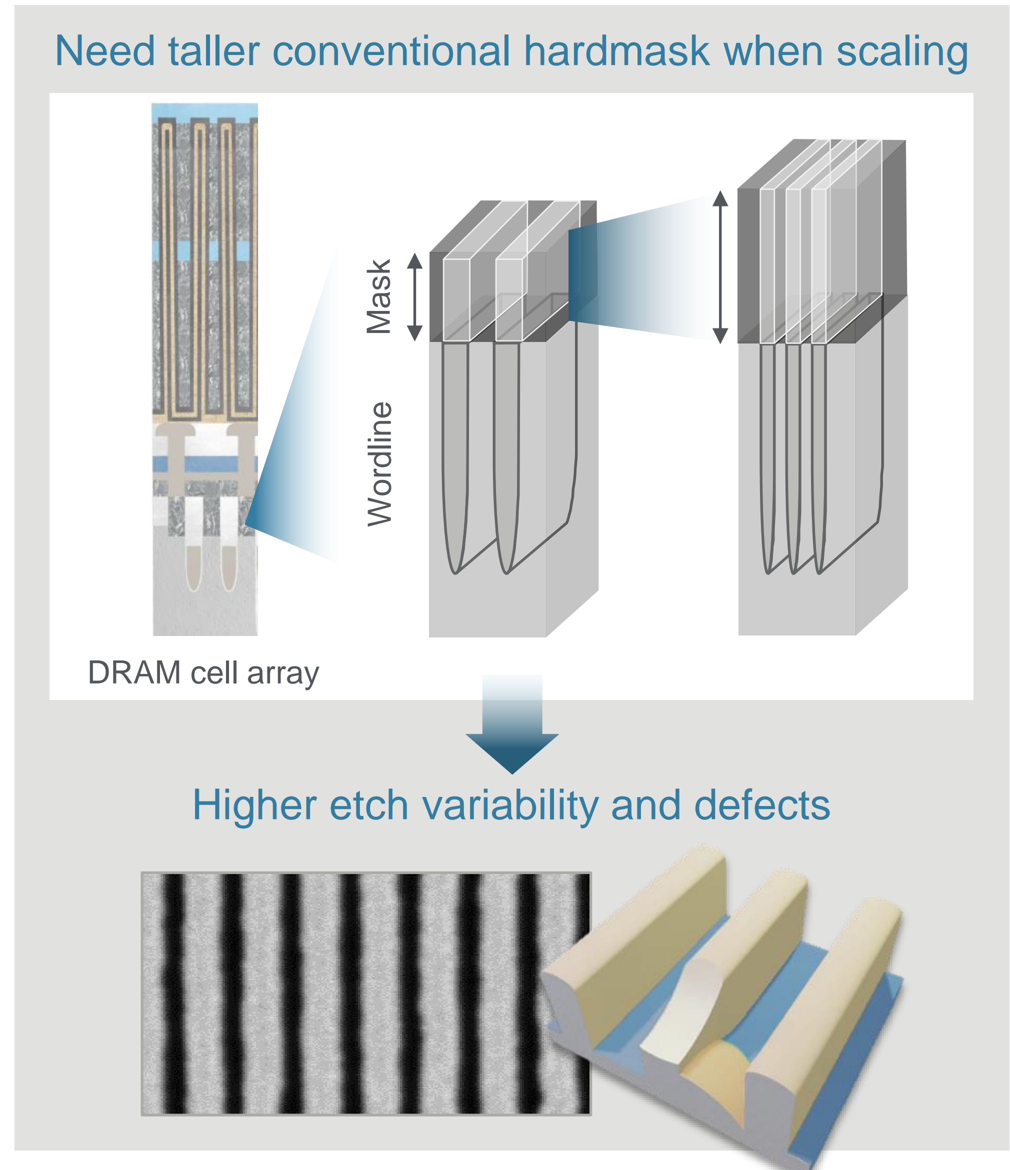
Co-optimizing Pioneer™ and Sym3™ Y Magnum™ for DRAM

Need taller conventional hardmask when scaling



Higher etch variability and defects

Higher selectivity with thinner Pioneer hardmask and Sym3 Y Magnum ion control

conventional hard mask

Pioneer

Sym3 Y Magnum ions

Etch Selectivity to Si

~2x

Conventional HM + Etch

Pioneer + Sym3 Y

Lower etch variability and defects

LWR

~25%

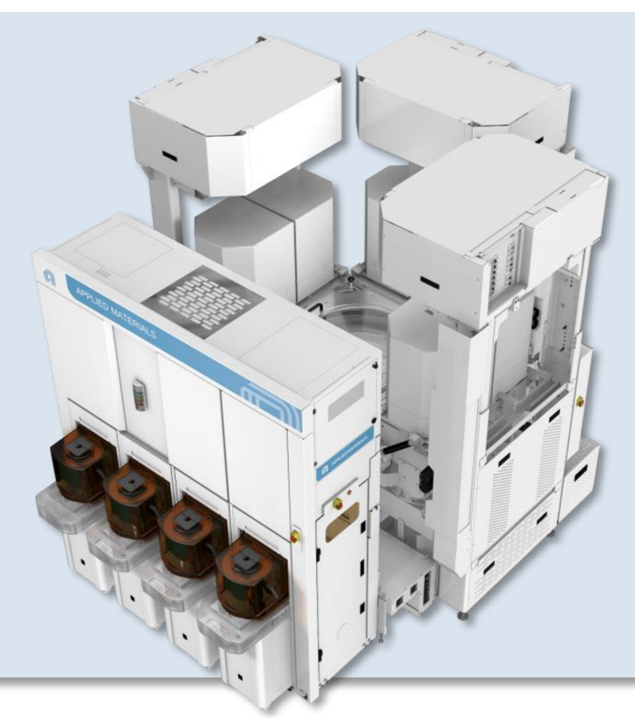
Conventional HM + Etch

Pioneer + Sym3 Y Magnum

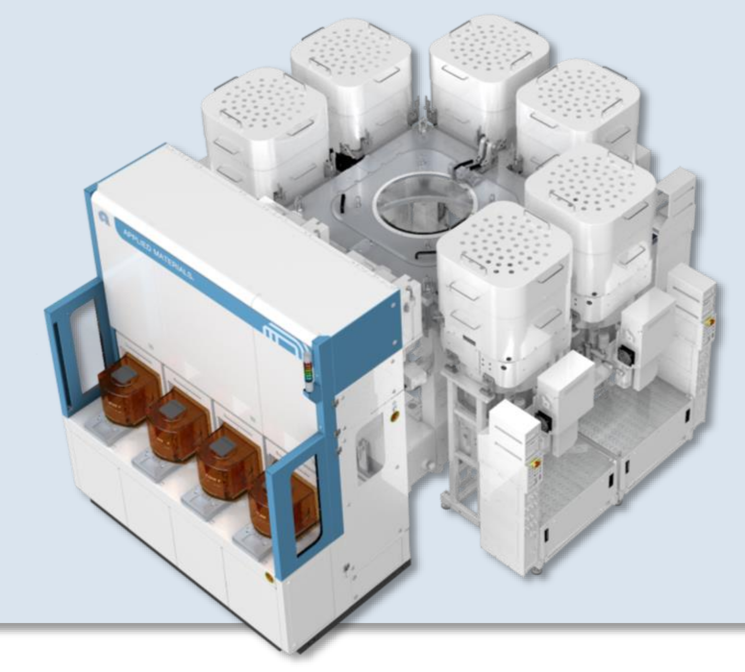
Source: Applied Materials

Pioneer™ and Sym3™ Y Magnum™ Business Momentum

Strong customer pull for new deposition and etch products



- ✓ Development and production tool of record positions at leading foundry-logic and memory customers
- ✓ Both products on track to generate hundreds of millions in annual revenue in coming years



Producer™ XP Pioneer™ CVD

Centris™ Sym3™ Y Magnum™ Etch

Introducing Contours for EUV

Design	SEM Imaging	Contour Extraction	Contours vs Design
Intended pattern	EUV-optimized image	High-quality contours of actual pattern from low-contrast image	Comparison of intended and actual patterns

Source: Applied Materials

Robust contours enable the accurate metrology required for patterning control in the angstrom era

Integrating Aselta Contour-Based Metrology

Accelerating design and time-to-yield with robust contours

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Multiple Applications for Aselta Contour-Based Metrology

Yield

R&D		Transfer / Ramp			High-Volume Manufacturing		
Multiple R&D cases VS, PV	Contours for OPC modeling VS	Litho-etch bias VS	EPE root cause VS, PV	Hotspot identification and characterization PV	EPE monitoring & control VS, PV	Scanner matching VS, PV	MBI* VS, PV

Process Development

Process Debug

Process Control

Time

VS = available on VeritySEM™
PV = available on PROVision™

*MBI: measurement-based inspection

News Summary

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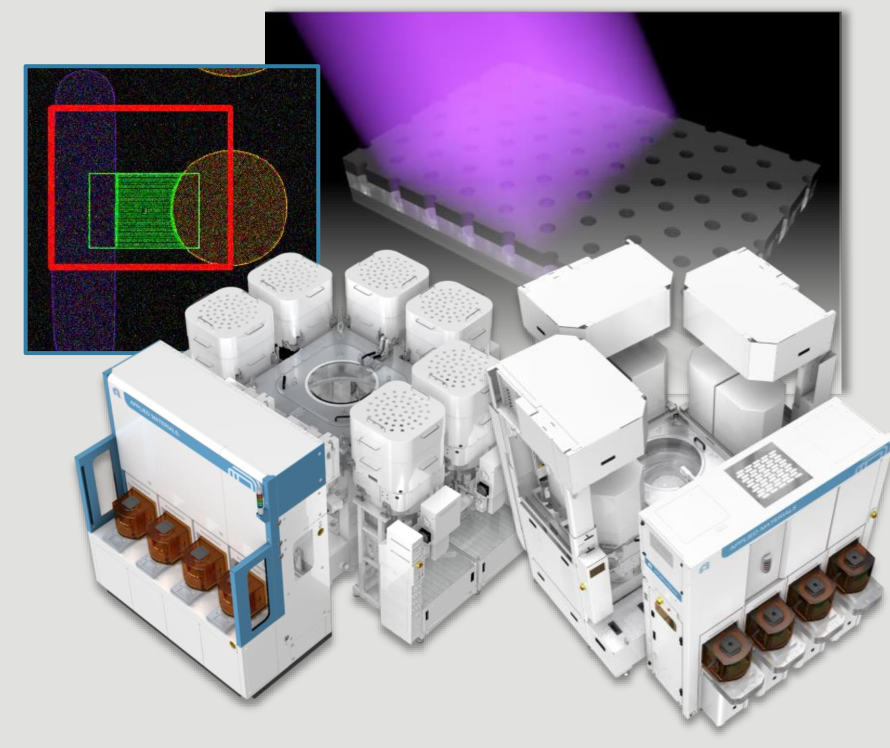

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MATERIALS®
make possible